Enabling and Promoting Sustainability through Digital API Ecosystems: An example of successful implementation in the smart city domain

Maurizio Brioschi, Michele Bonardi, Nadia Fabrizio, Alfonso Fuggetta, Emiliano Sergio Verga, Maurilio Zuccalà

> *"Digital ecosystems can provide every company, regardless of vertical or size, with the tools and expertise it needs to gain a competitive edge. But their biggest long-term potential may be societal, not just economic. Their unique, collaborative characteristics can enable them to tackle problems and challenges greater than those of any one company. Digital ecosystems could, for example, prove to be instrumental in slowing climate change."*
>
> Ibrahim Gokcen
> CTO at Schneider
> The Power of Digital Ecosystem is greater than their parts
> Forbes, May 2020

Recent studies have recognized that digital ecosystems can enhance the transformation of enterprises and the sustainability of cooperation networks by enabling a regulated and governed exchange of data between different stakeholders according to common rules. Thanks to digital ecosystems, data can be effectively distributed and leveraged to build innovative services in various contexts, such as smart cities or corporate solutions. In this paper we apply the Cefriel Digital Ecosystem Toolkit approach, which was first adopted to foster digital interoperability during the 2015 World Exposition in Milan, Italy. The goal of this lightweight approach is to combine technologies for building API-based solutions with governance processes and common participation guidelines. Moreover, we argue that this approach fosters data sustainability responding to the FAIR (Findability, Accessibility, Interoperability, Reusability) principles for data management and stewardship. Since 2015, this approach has been applied in several projects and featured by the European Commission's JRC and the US NIST. The Cefriel Digital Ecosystem Toolkit approach now supports the creation of many-to-many digital relationships between stakeholders operating in various domains, allowing the discovery and reuse of digital assets owned by companies and organizations of any type and size, as well as supporting the development of added value services for citizens and other end-users.

Introduction

In complex contexts like smart cities, tourism, and healthcare, the digitization of processes and services is based on a combination of many platforms, operating systems, and technologies. For instance, e-car navigation systems need to interact with the infrastructure of charging stations to plan a trip and schedule the stops required to recharge car batteries along the route. To reach the goal of comprehensive and effective digitization, digital systems and technologies should first be able to interoperate and exchange information between different players within coordinated and governed networks. These sociotechnical networks of organizations and technologies that collectively co-create value are called "digital ecosystems" (Nachira et al., 2007; Stanley et al., 2010). The term "ecosystem" originated with respect to biological communities to essentially describe the interactions between organisms of different species and their environment as an integrated system (Moore, 1993). Digital ecosystems now emerge spontaneously in

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the digital world, mainly because of the need for promoting data exchange between different players (Gelhaar & Otto, 2020).

For applications to real cases, the approach of creating digital ecosystems should tackle the following aspects:

- Digital ecosystems should not focus only on technologies and standards, they should also —or in particular —address the definition of proper governance processes and common guidelines for participation. While ecosystems sometimes emerge spontaneously, they require governance as well as rules for surviving in the long-term and for scaling (Immonem et al., 2014; Zeleti & Ojo, 2017; Gelhaar & Otto, 2020).

- Digital ecosystems can require many different legacy systems to exchange data. This is made possible by approaches based on Application Programming Interfaces (APIs) that are adopted by all parties as a grounding rule (Immonem et al., 2014). Digital ecosystem architectures should therefore be easily adaptable to legacy systems, in order to be widely adopted with affordable set up and running costs.

- Digital ecosystems should foster sustainability, meaning the capability of avoiding the depletion of resources (Dixon & Fallon, 1989). In particular, the ability to exchange data with related digital transformation, has passed from a specific need of software systems to a need at the enterprise level (Grzenda & Legierski, 2019). Very recent advances in ecosystem approaches to smart cities (Raghavan et al., 2020) show that the reuse and sharing of data with APIs can promote knowledge transfer. This also prevents wastage of physical and intellectual artifacts in recreating digital assets that already exist, for example, at the city or organization level.

In this paper, we present the Cefriel Digital Ecosystem Toolkit, a lightweight approach to creating digital ecosystems that combines interoperable technologies (APIs) with a special focus on governance processes and common participation guidelines. This approach supports data sustainability, and responds to the FAIR (Findability, Accessibility, Interoperability, Reusability) principles for data management and stewardship (Wilkinson et al., 2016). This approach is presented together with the example of a successful implementation of the toolkit applied to the smart city domain.

A Digital Ecosystem Model Fostering Sustainability

Various approaches can be adopted to build a digital ecosystem (Gelhaar & Otto, 2020).

First, it is essential to break down digital silos that typically exist within organizations so to unlock the access to heterogeneous systems and interconnect

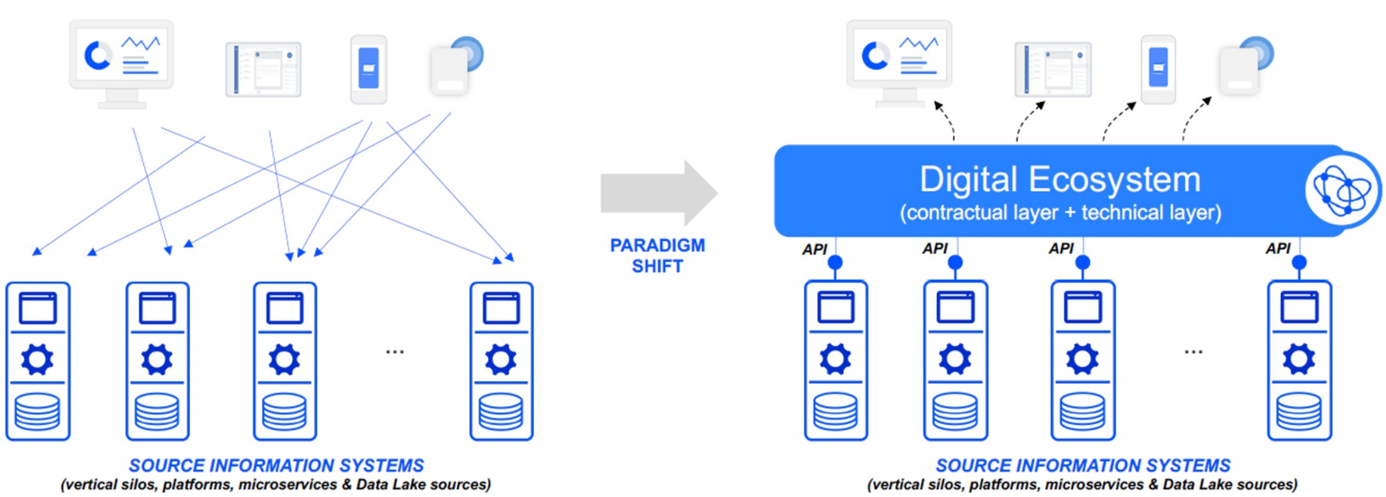


Figure 1. Digital Ecosystem (contractual framework and technical layer)

them. This interconnection can be made without the invasive intervention to a legacy data system, but rather just by promoting interoperability with the addition of APIs. Thanks to this cheap technical intervention, additional business value from data can be unlocked in a sustainable way because data can be reused to create different services, decoupling the backend databases from end-user applications. Furthermore, APIs can be considered reusable building blocks for the same data in different user scenarios. This is not just a technical issue, since APIs must be exchanged according to common rules and processes. For this reason, a digital ecosystem should consider not only the technical interoperability layer, but also a regulated contractual framework. The APIs exchanged are defined as "e-APIs" (ecosystem APIs), which take into consideration also the fulfilment of comprehensive rules of adoption (see Figure 1).

The Cefriel Digital Ecosystem Toolkit addresses the combination of a contractual framework and a technical layer. This toolkit consists of a "visible" part (an online environment to foster communication and the findability of e-APIs), while the most important core components of it are "intangible" (see Figure 2):

- Technical guidelines addressing both interoperability standards and metadata to make technical interfaces reusable from a business point of view.

- Processes that rule the way e-APIs are requested and their lifecycle.

- A supporting team for comprehensive ecosystem governance and dissemination/onboarding actions.

According to this toolkit, participants within a digital ecosystem can exploit one or both of the following capabilities:

- Unlocking additional business value from digital assets and sharing them in a regulated way in the form of e-APIs.

- Enriching the software solutions (for example, websites, mobile apps, and monitoring dashboards) they offer to end-users by using e-APIs made available by other participants.

The most important role within the toolkit (composed of common rules, processes, and roles, see Figure 3) is the governance exercised by the Ecosystem Management Board. The Board takes care of:

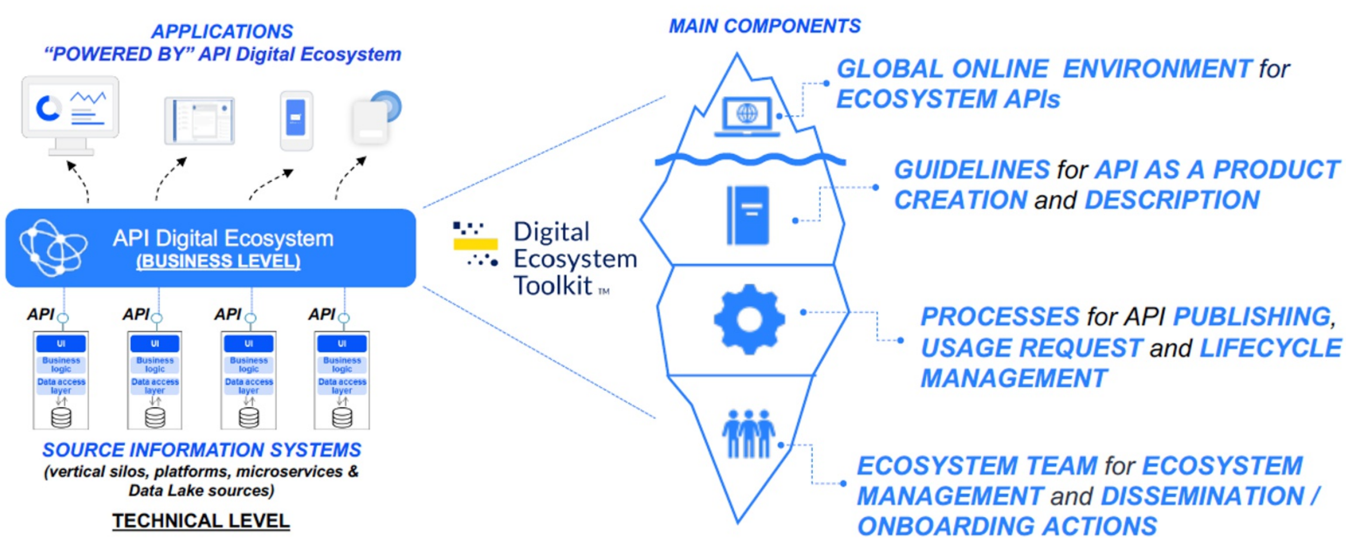


Figure 2. Cefriel Digital Ecosystem Toolkit - Main Components

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- Operational governance to manage processes and the online environment to describe, share, and request e-APIs.

- Technical governance, including the interoperability technical standards to exchange data (for example, REST APIs).

- Onboarding governance to promote sharing and usage of e-APIs, in order to create valuable business scenarios.

- Strategical governance to define the trajectory and main areas of interest for ecosystem development.

The contractual framework is based on the concept of “coopetition” (Luo, 2004), where individual ecosystem players compete according to their own business needs, while at the same time cooperating with other players in the ecosystem according to common rules.

The Cefriel Digital Ecosystem Toolkit approach can be exploited at various levels: within a single organization (intranet), in a closed set of organizations (extranet), or at the Internet level. At the time of writing, this framework has been applied in a variety of scenarios (for example, mobility, energy, crisis management), settings (extranet partners networks and Internet), and with different software technologies and platforms. In the following section, we present a real use case.

A Digital Ecosystem Case Study: E015

The E015 Digital Ecosystem (https://www.e015.regione.lombardia.it/) was the first case for implementing the Cefriel Digital Ecosystem Toolkit approach. The E015 initiative was initially promoted by the main Italian associations of companies (Confindustria, Confcommercio, Chamber of Commerce). The E015 Digital Ecosystem Chamber of Commerce of Milan, Assolombarda and Unione del Commercio, with the scientific coordination of Cefriel) to serve the Milano 2015 World Exposition. It was conceived as a relevant opportunity to introduce innovation in many aspects of the urban daily life of visitors and citizens, including infrastructures, tourism, cultural and social life, services, and facilities. At the end of Expo 2015, the regional government of Lombardy took over governing the E015 Digital Ecosystem as a strategic asset to promote sustainable digitalization in the surrounding territory.

At the time of writing, more than 170 e-APIs have been shared in the E015 Digital Ecosystem. These e-APIs have been used in developing more than 100 end-user digital solutions, thus enabling the creation of more than 460 digital business relationships. The National Institute of Standards and Technology of the United States (NIST) considered E015 in developing an IoT-Enabled Smart

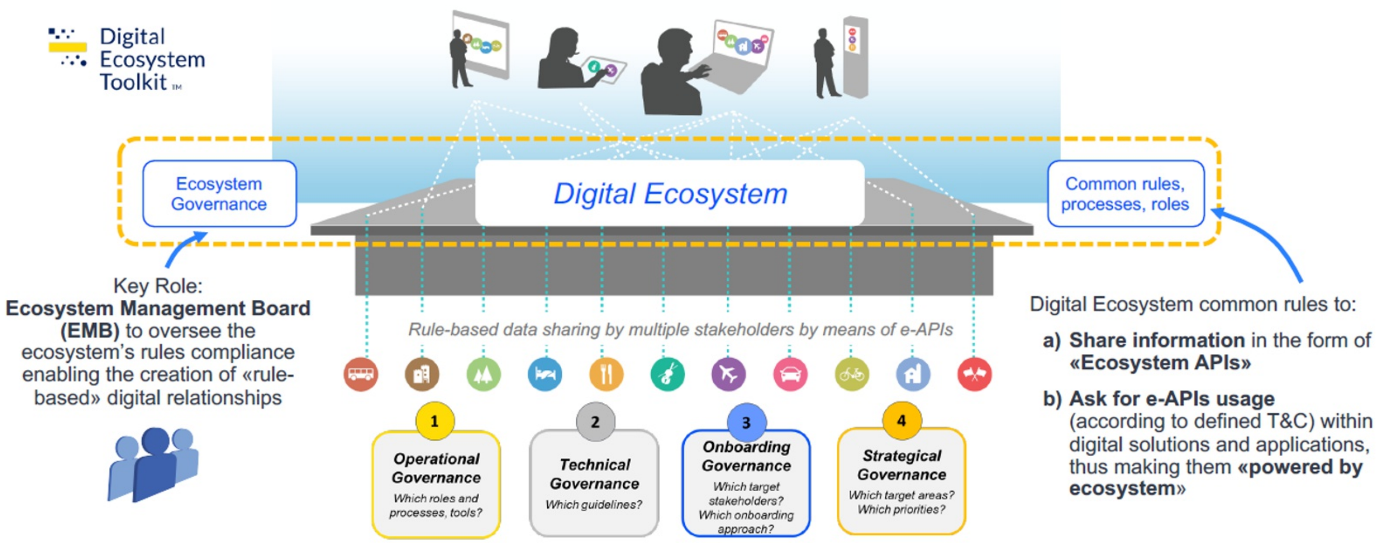


Figure 3. The Ecosystem Management Board Roles

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City Framework (Burns et al., 2018), while the European Commission's Joint Research Center (JRC) cited E015 as a best practice for governments as ecosystem owners/controllers (Vaccari et al., 2020).

The E015 Digital Ecosystem used in Italy was first adopted for sustainable development to promote the use of public transportation. For example, the main Italian airport and rail/road transportation companies provide citizens with real-time integrated information about the status of flights, trains, and buses by sharing their data via the E015 ecosystem.

E015 transportation data has been used also to support infrastructure planning and developing cost-benefit analysis. The LINKS Foundation, on behalf of the Piedmont Region and Rete Ferroviaria Italiana, has leveraged information available in E015 to assess the impact and accessibility of railways between Milan and Turin. Such information is being used for several purposes, for example, to make decisions about creating new rail stations.

E015 has been adopted also for environmental protection. The Lombardy Region created an integrated inter-regional dashboard to coordinate local actions that could mitigate air pollution, where the municipalities of regions overlooking the river Po's fluvial basin get updated in real-time about restrictions. The restrictions are automatically defined by an algorithm that uses e-APIs with weather data, while data about real-time restrictions get shared in turn by means of an e-API.

The same e-API about pollution restrictions has been used to build the requalification sector within the SPICA project (Zuccalà et al., 2019). Thanks to a web application that collects and elaborates data from indoor and outdoor sensors, the inhabitants of 80 apartments in various areas of Milan could better understand the impact of their behaviors on the environment and energy savings.

The same data for weather stations is also used to monitor the water levels of the Pagnona Dam (located in Premana, Italy) in real-time, as a way to improve the territory's resiliency and safety. In case of heavy rains and severe weather, it is possible to forecast the water level in the dam, thus preventing damage scenarios and properly defining evacuation models and emergency plans.

Discussion

The E015 use case presented above shows how adopting the Cefriel Digital Ecosystem Toolkit enables the creation of useful digital solutions to help citizens make smarter decisions or improve the efficiency of smart city processes. Moreover, digital solutions can be created in a quick and simple way by reusing digital assets shared as e-APIs and unlocking additional business value from data. The toolkit framework is lightweight and scalable at different levels to create a digital ecosystem at the level of a single place, for example, airport, railway station, or shopping mall, where different players interact with and need to exchange data, or all along complex supply chains by enabling data exchange between companies and suppliers. Sharing technical APIs to access existing databases promotes a smooth transition from legacy systems and conventional solutions to innovative scenarios, yet without having to make excessive investments, thus ensuring sustainability also from an economic point of view.

The Cefriel Digital Ecosystem Toolkit can be considered also as an enabler for adopting FAIR principles with interoperability and information exchange among multi-stakeholder systems. The toolkit framework meets the main FAIR principles defined by Wilkinson and colleagues (2016):

- *Findability*: e-APIs to access data enable both a technical and business point of view, and can be searched inside the digital ecosystem's online environment.
- *Accessibility*: data gets compiled according to vendor-independent interoperability technical protocols (for example, REST APIs).
- *Interoperability*: the framework fosters interoperability among databases and promotes standardized glossaries for data representation.
- *Reusability*: the approach promotes a sustainable valorization of existing data, which can be used according to digital ecosystem rules and processes.

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In the Lombardy Region, the E015 Digital Ecosystem has been included into a regional law as an official way of promoting data transparency and data exchange between public and private players. Thanks to this law, the Lombardy regional government can ask utilities that win public contracts to share the data generated with those public contracts as e-APIs on the E015 Digital Ecosystem. For example, the utility which wins a contract for installing and managing charging stations for electric cars has to share into the E015 Digital Ecosystem data about position and availability of the charging infrastructure. This approach has been used to promote the territory's digitalization in a sustainable and shared way, at no cost for the public administration. In addition, it assures the availability and accessibility of digital assets, which can be used by other players in creating new services. The vision is to create a live "digital twin" of the territory, with the possibility of accessing in real time all the unlocked digital assets in a common digital ecosystem.

Conclusion

This paper presented an approach to lightweight digital ecosystems. The main achievement of this approach, on the basis of the E015 Digital Ecosystem experience, has been to enable business relationships based on data sharing between different entities, decoupling the IT from the business aspects, and thus achieving a concrete way to reuse and discover data and digital artifacts. This constitutes a sustainable and FAIR approach in practice, especially for reusability. The given examples show how the approach proposed in E015 can be successfully adopted not only within various business sectors, but also in promoting fluid data exchange between different sectors. From this point of view, the digital ecosystem toolkit approach combines simplicity and adoption velocity (because it is lightweight and allows using legacy systems) with transverse effectiveness in addressing data exchange issues between heterogeneous players (including public institutions, big companies, and startups). We continue to work on developing the technical and logical aspects of the model, including the introduction of blockchain-based components and smart contracts to automate internal processes in a secure way. Likewise, we aim to further federate and complement various API-based digital ecosystems built according to the Cefriel Digital Ecosystem Toolkit.

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Citation: Brioschi, M., Bonardi, M., Fabrizio, N., Fuggetta, A., Verga, E.S., Zuccalà, M. Enabling and Promoting Sustainability through Digital API Ecosystems: An example of successful implementation in the smart city domain. Technology Innovation Management Review, 11(1): 4-10.

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Keywords: FAIR, digital ecosystem, interoperability, sustainability

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Emiliano Sergio Verga has been working at Cefriel as a Digital Ecosystem Manager since 2013. His main role is the Scientific Coordination of the Lombardy Region's E015 Digital Ecosystem.

Maurilio Zuccalà has been principal investigator in research projects (FP6, FP7, H2020, EIT) since 2004 in the field of API economy, smart cities, digital platforms, and service ecosystems. He has authored texts in peer reviewed journals, books, and conferences and is a technical leader for the urban data platform of the H2020 "Sharing Cities" lighthouse project in Milan.